# THE SOLAR SYSTEM

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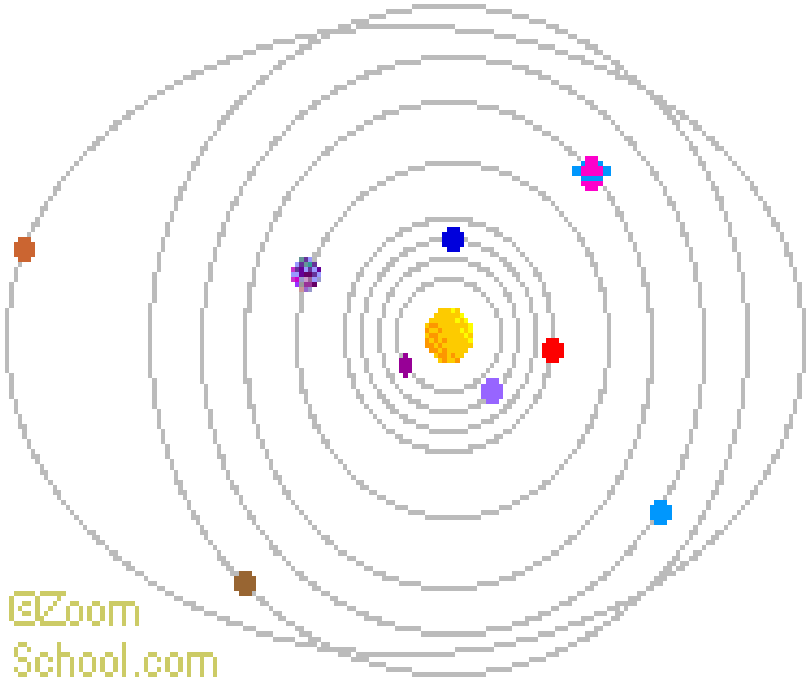
# ORIGIN OF THE UNIVERSE

- The Big Bang
  - The Big Bang Theory is the dominant scientific theory about the origin of the universe. According to the big bang, the universe was created sometime between 10 billion and 20 billion years ago from a cosmic explosion that hurled matter in all directions.

# THE SOLAR SYSTEM

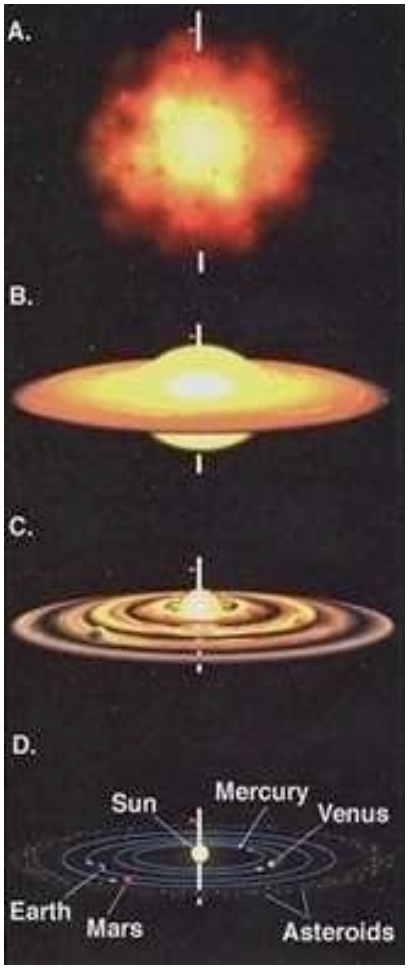
- Our solar system consists of the sun, nine planets (and their moons), an asteroid belt, and many comets and meteors. The sun is the center of our solar system; the planets, over 61 moons, the asteroids, comets, meteoroids, and other rocks and gas all orbit the Sun.



# ORIGIN OF THE SOLAR SYSTEM

- It is thought that the Solar System formed according to what is known as the **Nebular Hypothesis.** About 4.5 billion years ago it is believed that the Solar System consisted of a large cloud of gas and dust, called a nebula. This cloud started rotating, and the dust particles combined to form planetesimals. As the cloud rotated faster, it flattened, and the planetesimals combined to form, first of all, the Sun at the center, and secondly, the planets in orbit around the Sun. This model explains qualitatively many features of the Solar System, including the fact that the planets essentially all revolve around the Sun in the same plane.

# NEBULAR HYPOTHESIS




Initial contraction and compressional event

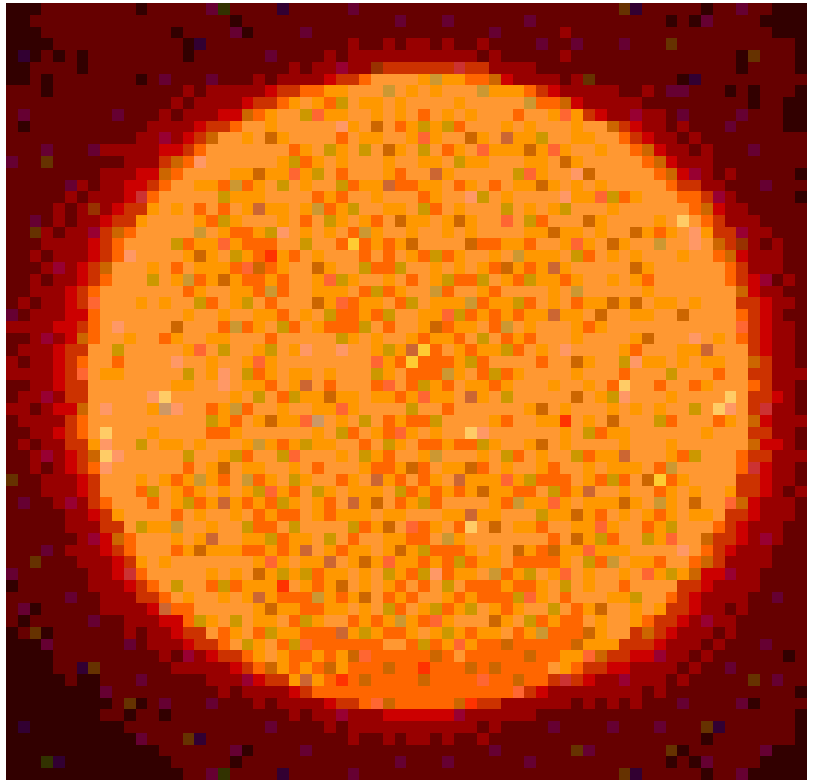
Increased spin and disk formation, and sun begins to burn

Planetesimals form about 4.55 billion years ago

Planets form out of planetesimals - completed by about 4.45 billion years ago

# THE SUN

- Our sun is a star located at the center of our Solar System. It is a huge, spinning ball of hot gas and nuclear reactions that lights up the Earth and provides us with heat.

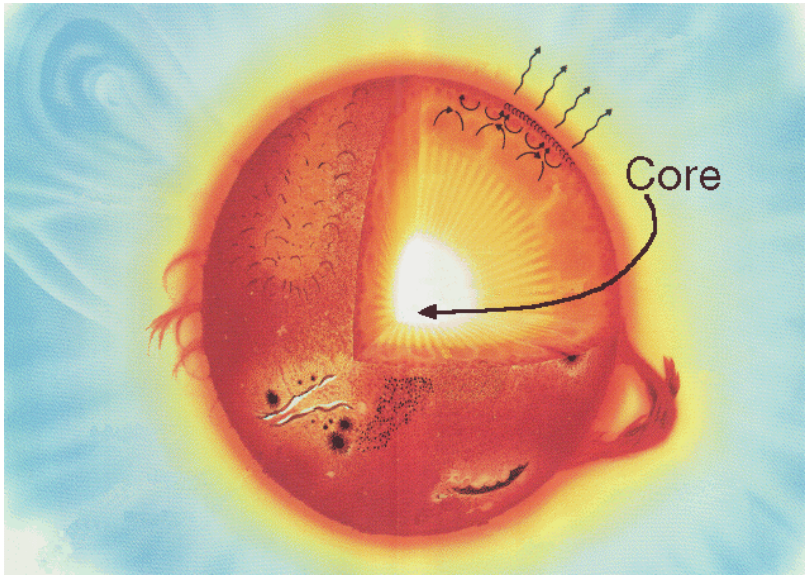


# STRUCTURE OF THE SUN

- Core
- Radiative Zone
- Convective Zone
- Photosphere
- Chromosphere
- Corona

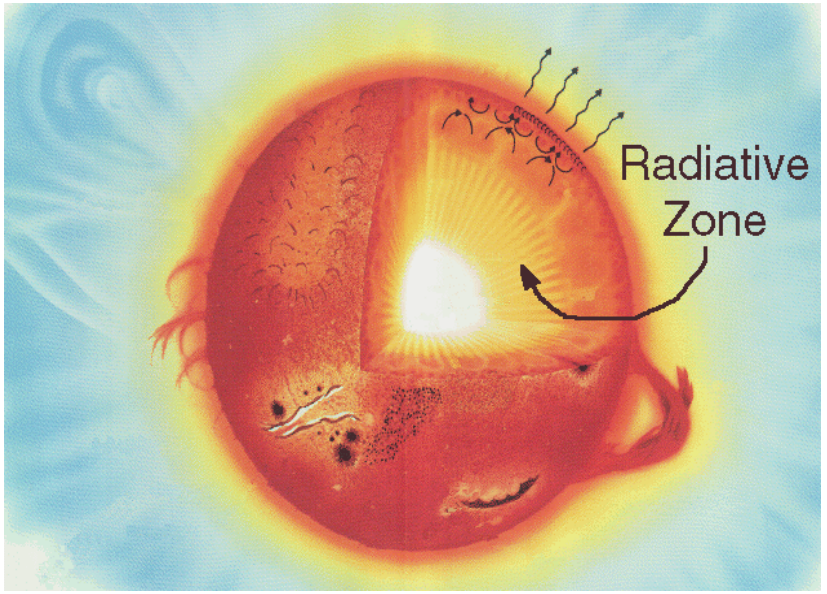
# CORE

- The core is the center of the sun.  It has a very high temperature and pressure. The temperature is roughly 15 million °C. At this temperature, nuclear fusion occurs, turning four hydrogen nuclei into a single helium nucleus plus a **LOT** of energy. This "hydrogen burning" releases gamma rays (high-energy photons) and neutrinos (particles with no charge and almost no mass).



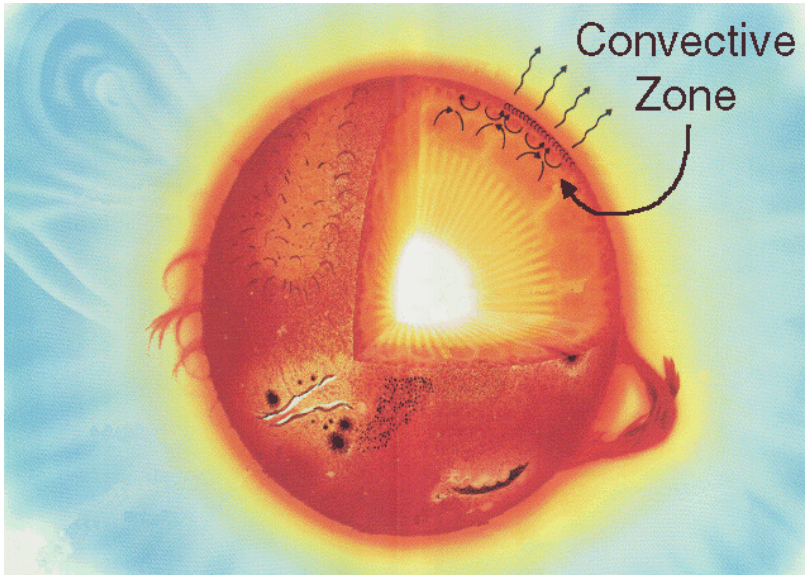
# RADIATIVE ZONE

- The next layer out from the core is the radiative  zone which emits radiation. This radiation diffuses outwards. The temperature ranges from 15 million °C to one million °C. It may take photons of radiation millions of years to pass through the radiative zone as they gradually make their way outwards.



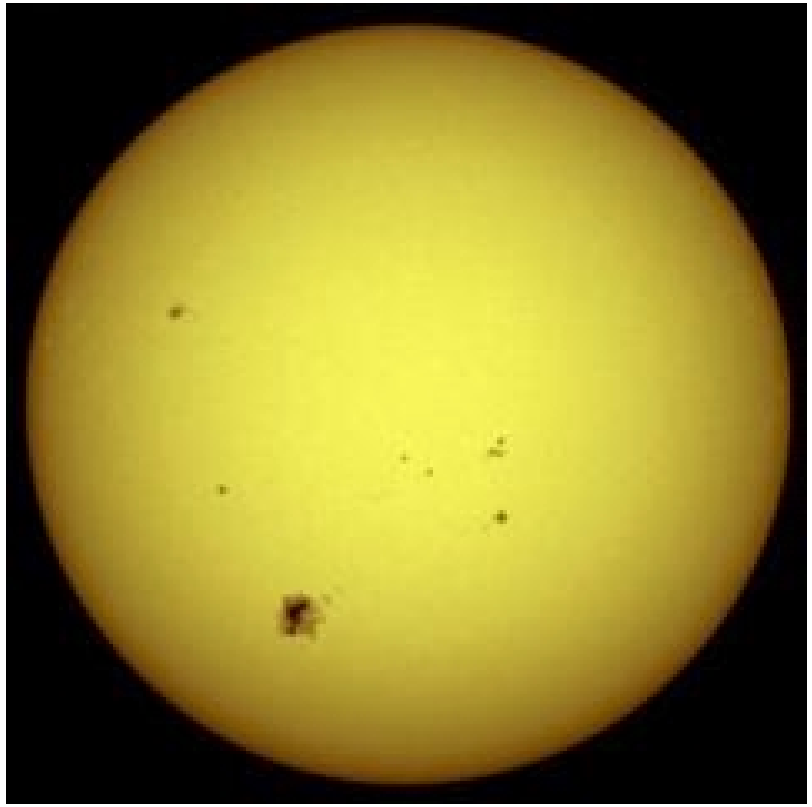
# CONVECTIVE ZONE

- In the convective zone photons continue to make their way outwards via convection (towards lower temperature and pressure). The temperature ranges from one million °C to 6,000 °C.



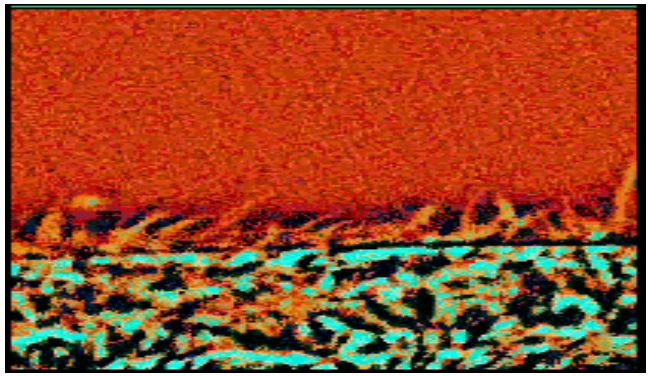
# PHOTOSPHERE

- The photosphere is the lower atmosphere of the Sun and the part that we see, since it emits light at visible wavelengths. This layer is about 300 miles (500km) thick. The temperature is about 5,500 °C.



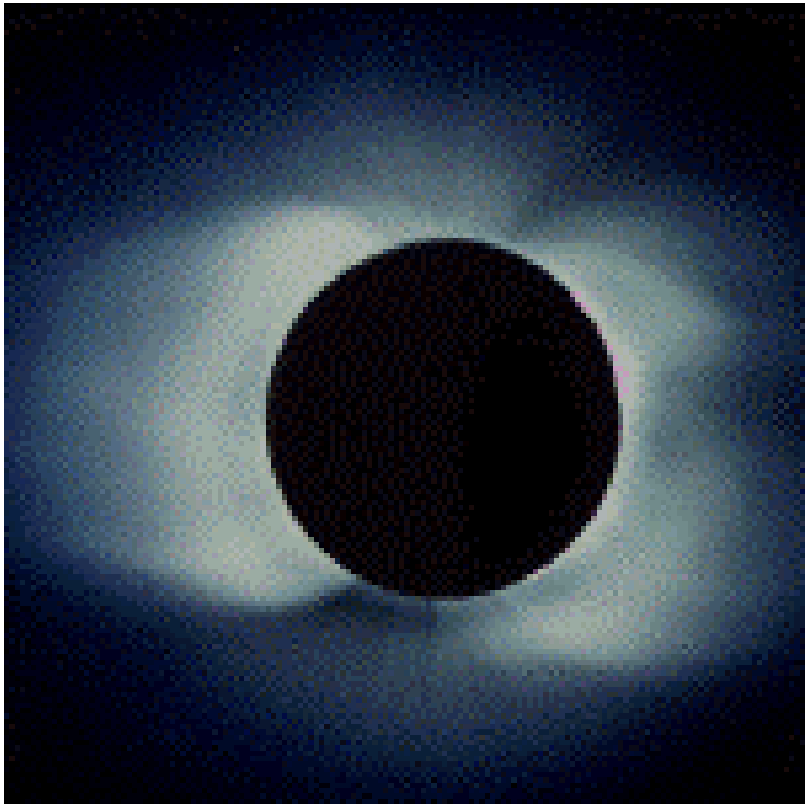
# CHROMOSPHERE

- The chromosphere , a reddish layer, is an area of rising temperatures. The temperature ranges from 6,000 °C (at lower altitudes) to 50,000 °C (at higher altitudes). This layer is a few thousand miles (or kilometers) thick. It appears red because hydrogen atoms are in an excited state and emit radiation near the red part of the visible spectrum. The chromosphere is visible during solar eclipses (when the moon blocks the photosphere).



# CORONA

- The corona is the outer layer of the Sun's atmosphere. It extends for millions of miles and the temperatures are tremendous, reaching one million °C.  Holes in the corona occur where the Sun's magnetic field loops out into space. These coronal holes may be the source of the solar wind, a stream of energetic particles that permeate the Solar System.

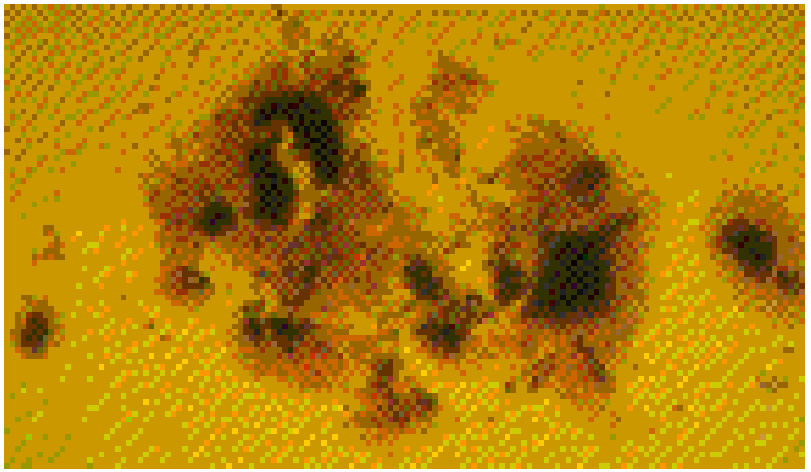


# SOLAR PHENOMENA

- Sunspots
- Solar flares
- Solar wind

# SUNSPOTS

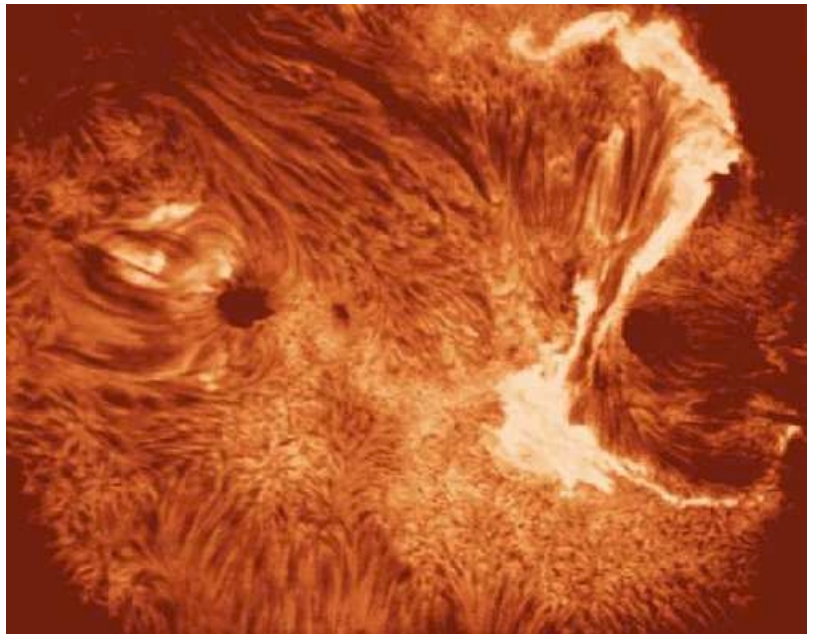
- Sunspots are relatively cool, dark patches on the sun's surface. They come in many shapes and sizes; they often appear in groups. These spots are much bigger than the Earth and can be over 10 times the diameter of the Earth’s. Sunspots occur where the sun's magnetic field loops up out of the solar surface and cools it slightly, making that section less bright. These disturbances in the sun's magnetic field make the sunspot about 2700°F (1500°C) cooler than the surrounding area.



Sunspots may have a long-term connection with the Earth's climate. Scientists are currently debating whether ice ages on Earth are related to the Sun having fewer sunspots than usual.

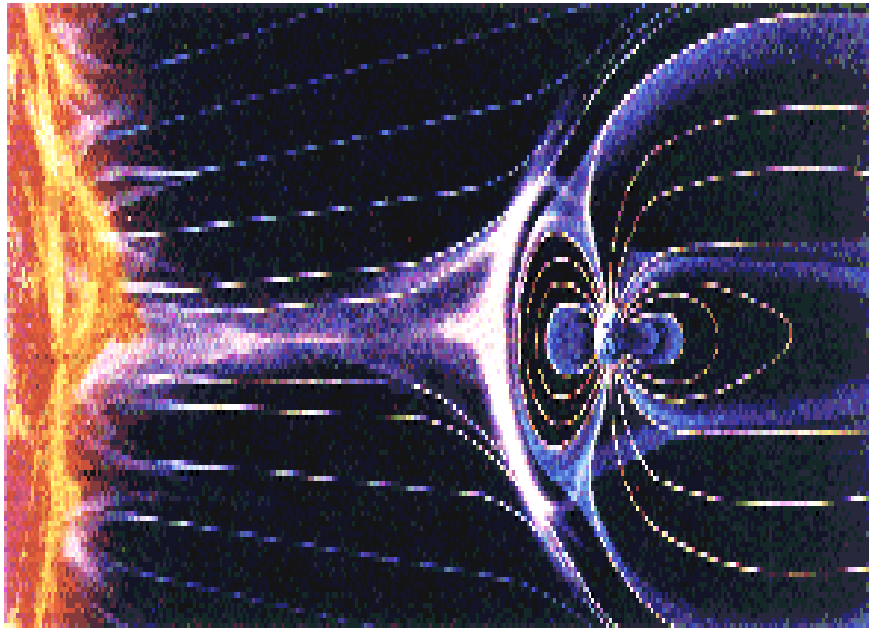
# SOLAR FLARES

- A solar flare is defined as a sudden, rapid, and intense variation in brightness on the sun and occurs when magnetic energy that has built up in the solar atmosphere is suddenly released. Radiation is emitted across virtually the entire electromagnetic spectrum. The amount of energy released is the equivalent of millions of 100-megaton hydrogen bombs exploding at the same time. Solar flares directly affect the ionosphere and radio communications on the Earth, and they also release energetic particles into space.



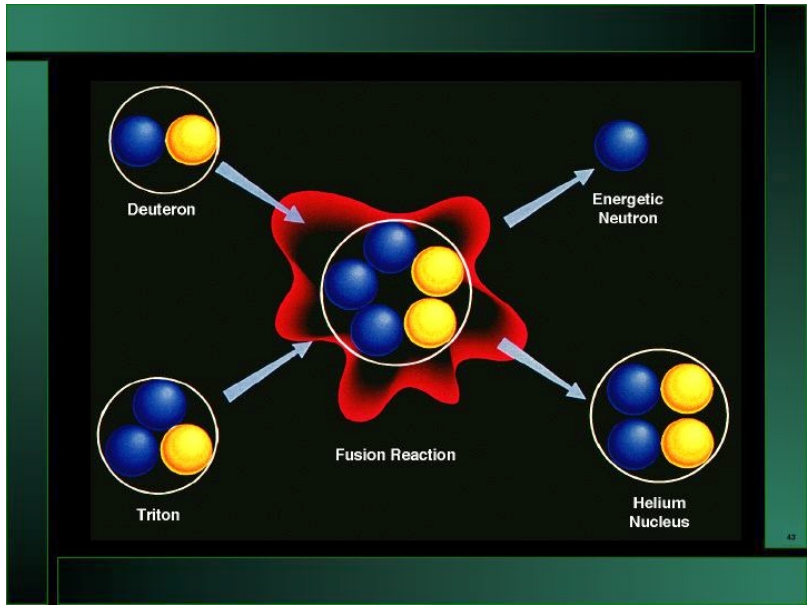
# SOLAR WIND

- The solar wind is composed of high-speed charged particles constantly blowing off the Sun. The solar wind may be viewed as an extension of the outer atmosphere of the Sun (the corona) into interplanetary space.  Solar winds are believed to be responsible for power line surges, radio interference, and the aurora borealis (northern lights). The excess radiation from the solar wind may also be responsible for shortening the life of satellites and harming astronauts.



# THE SUN'S ENERGY

- The Sun's energy is produced by nuclear fusion reactions. Fusion is the combining of atomic nuclei into larger nuclei with the release of energy. In the Sun's interior, 4H (hydrogen) nuclei combine (through a step by step process) to form a single He (helium) nucleus. This requires a temperature of tens of millions of degrees C.

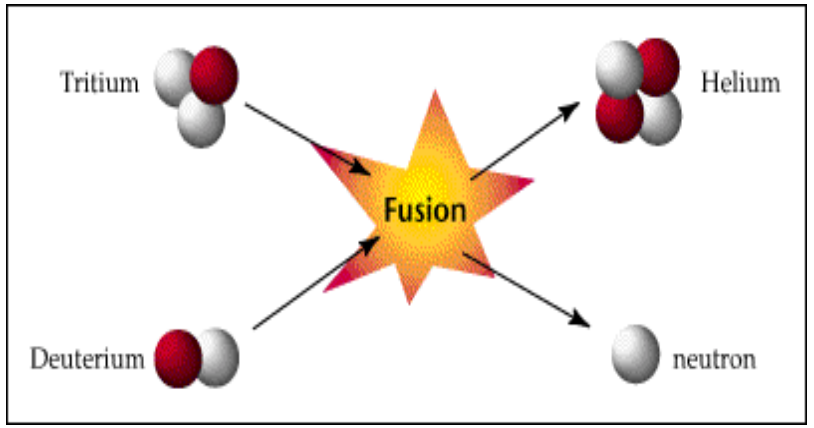


# TYPES OF NUCLEAR REACTIONS

- Nuclear fusion
- Nuclear fission

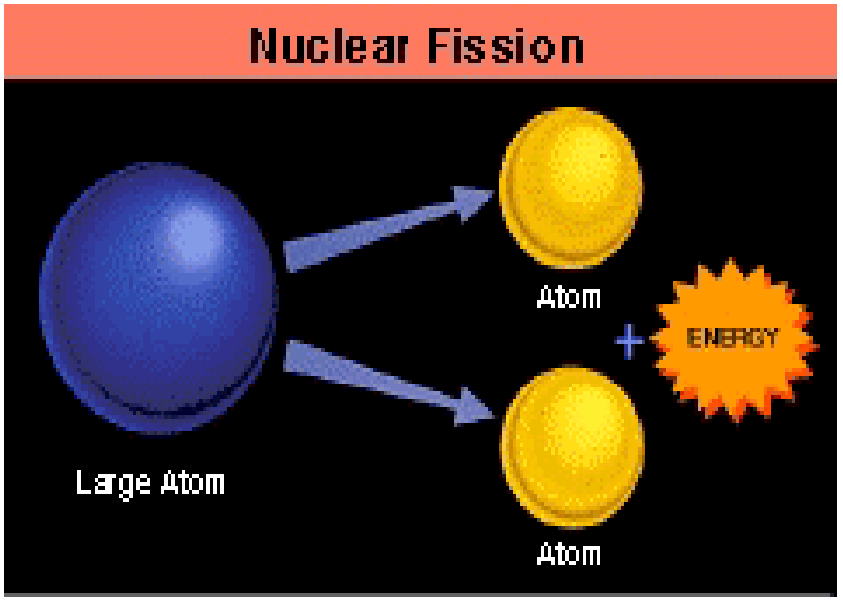
# NUCLEAR FUSION

- Nuclear fusion is the formation of heavier elements from smaller, less dense elements on the sun. Scientists are experimenting with nuclear fusion by changing deuterium and tritium to helium. Deuterium and tritium are isotopes of hydrogen, having 2 and 3 neutrons in the nucleus, respectively. Nuclear fusion has been achieved in the laboratory, but the amount of energy given off in the reaction is equal to or less than the energy required to produce the reaction. Fusion would be the preferred way to produce electricity because the half-life of the product is less than that of the products produced in a fission reaction. Thus, the amount of nuclear waste generated would be less.



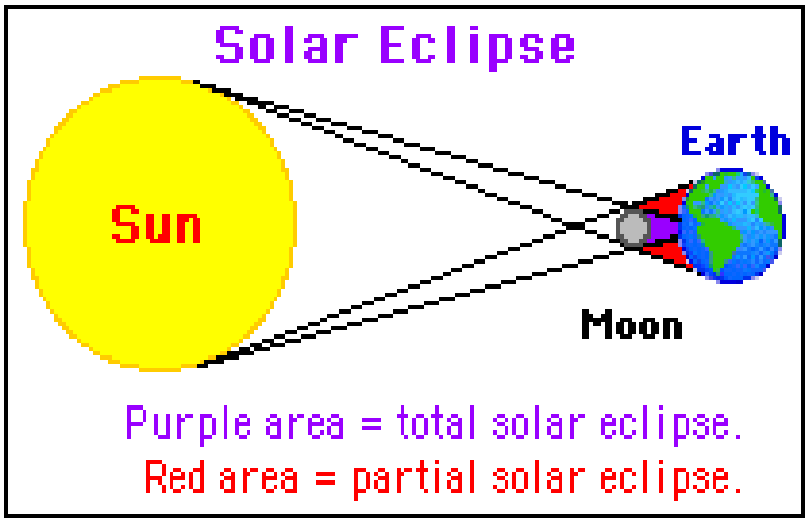
# NUCLEAR FISSION

- Nuclear fission is the splitting of large-nuclei elements, such as uranium or plutonium, into smaller pieces with the release of considerable energy. This process is what we use on Earth to produce electricity in nuclear powerplants and to make atomic weapons. These reactions produce radioactive products that have long half-lives and remain radioactive for thousands of years.



# SOLAR ECPLIPSE

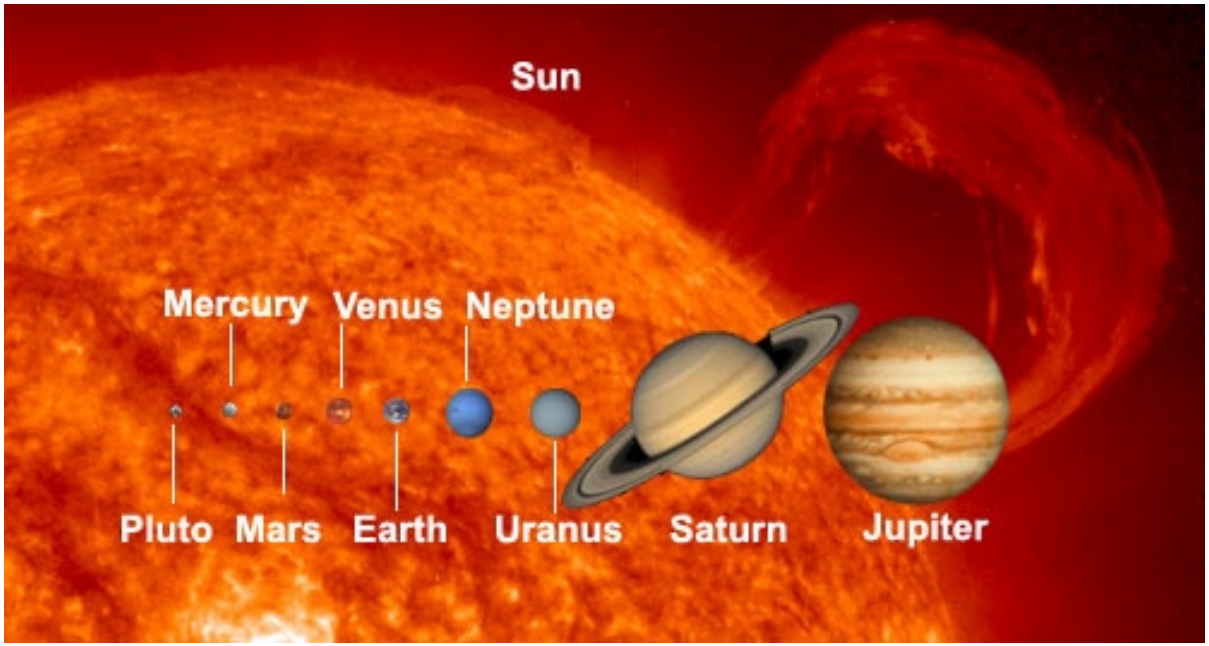
- A solar eclipse occurs when the Moon, during its monthly trip around the Earth, happens to line up exactly between the Earth and the Sun.



# THE PLANETS

- The nine planets that orbit the sun are (in order from the sun): Mercury, Venus, Earth, Mars, Jupiter (the biggest planet in our Solar System), Saturn (with large, orbiting rings), Uranus, Neptune, and Pluto. A belt of asteroids (planetoids made of rock and metal) orbits between Mars and Jupiter. The planets all orbit the sun in roughly circular orbits that lie in the same plane, called the ecliptic. The exception is Pluto that has an elliptical orbit tilted over 17° from the ecliptic.

# RELATIVE SIZE OF THE PLANETS

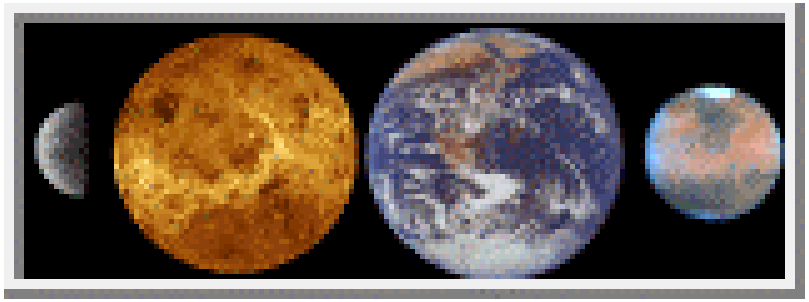


# TYPES OF PLANETS

- Inner planets or terrestrial planets
- Outer planets or Jovian planets

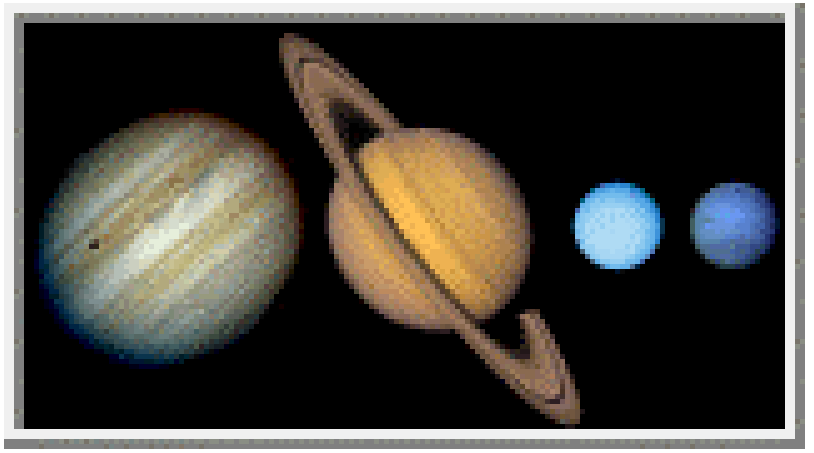
# INNER PLANETS

- The inner planets, also called terrestrial planets, are: Mercury, Venus, Earth, and Mars. They are relatively small, composed mostly of rock and metal, and have few or no moons.



# OUTER PLANETS

The outer planets include: Jupiter, Saturn, Uranus, and Neptune. Jupiter, Saturn, Uranus, and Neptune are known as the Jovian (Jupiter-like) planets. They have a gaseous nature and have many moons. The Jovian planets are also referred to as the gas giants.



# OUTWARD OF THE OUTER PLANETS

- Pluto
- Kuiper Belt
- Oort Cloud

# Pluto

- Pluto is usually the most distant planet from the Sun, but because of its elliptic orbit Pluto crossed inside of Neptune's orbit in 1979 and crossed back out again in 1999. Compared to the other planets, very little is known about Pluto. Pluto is the smallest planet and even smaller than several other planets moons. Pluto is probably composed of frozen rock and ice. It has one moon (Charon).

Pluto and Charon

# Kuiper Belt

- The Kuiper Belt is named after Gerard Kuiper who suggested its existence in 1951. It is a zone outside the orbits of Neptune and Pluto in which icy solar system objects were first found in 1992. These objects probably represent the remnants of a much larger population of such objects, formed in the early phase of the solar system, some 4.5-4.7 billion years ago. The outermost planet, Pluto, maybe the largest member of this class of objects. According to current ideas, the short-period comets (comets that have been observed at regular intervals) in the inner solar system come from the Kuiper Belt.

# Oort Cloud

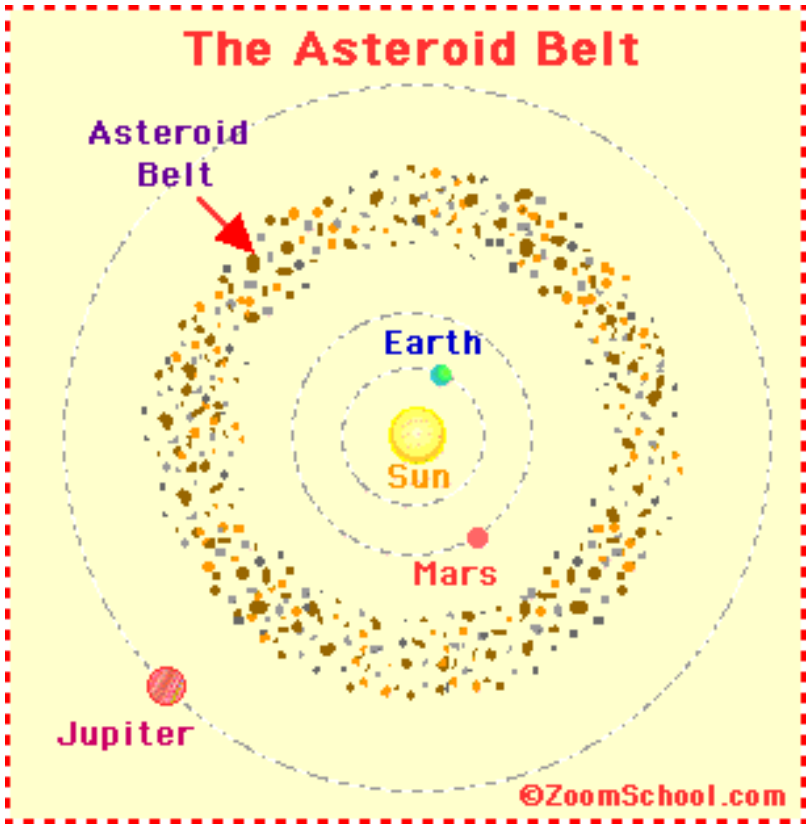
- In 1950, a Dutch astronomer, Jan Oort, postulated a shell of comets surrounding the solar system at about 50,000 AU ( one AU or astronomical unit is 93 million miles). Today scientists agree that there is a giant cloud of comets outside the orbits of the planets. The Oort cloud is now known to extend from 1,000-100,000 AU. The Oort cloud may contain a trillion objects. This is the source of long-term comets, which are seen only once.

# SMALLER BODIES

- There are other smaller objects that orbit the Sun, including asteroids, comets, and meteoroids. Comets, asteroids and meteoroids are all examples of "space debris." They are remnants of the material left over from that period of time when the solar system formed.

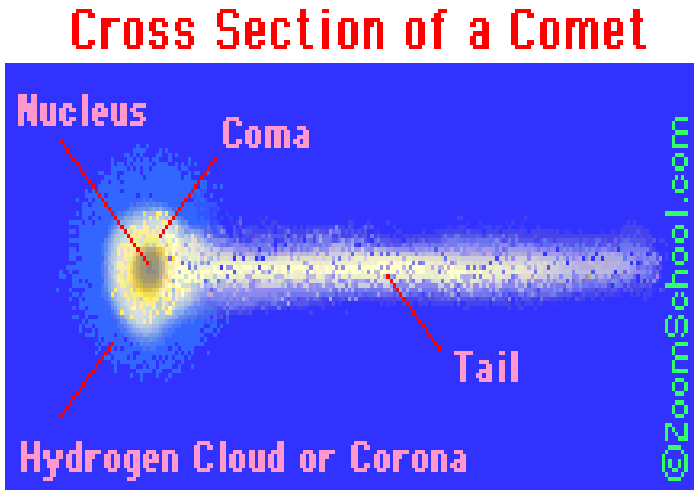
# Asteroid Belt

- Asteroids are rocky or metallic objects, most of which orbit the Sun in the asteroid belt between Mars and Jupiter. A few asteroids approach the Sun more closely. None of the asteroids have atmospheres.



# Comets

- A comet is a small, icy, celestial body that orbits around the sun. It is made up of a nucleus (solid, frozen ice, gas and dust); a gaseous coma (water vapor, $CO_2$, and other gases); and a tail (dust and ionized gases). Its long tail of gas and dust always points away from the sun, because of the force of the solar wind. Comets may come from the Oort cloud (long-term comets that appear only once) or the Kuiper belt (short-term comets that appear regularly like Haley's comet).



# Meteoroids

- Meteoroids are small bodies that travel through space. They are smaller than asteroids; most are smaller than a pebble. Most meteoroids come from asteroids that are broken apart by impacts with other asteroids. Other meteoroids come from the Moon, comets, and the planet Mars.

# THE EARTH

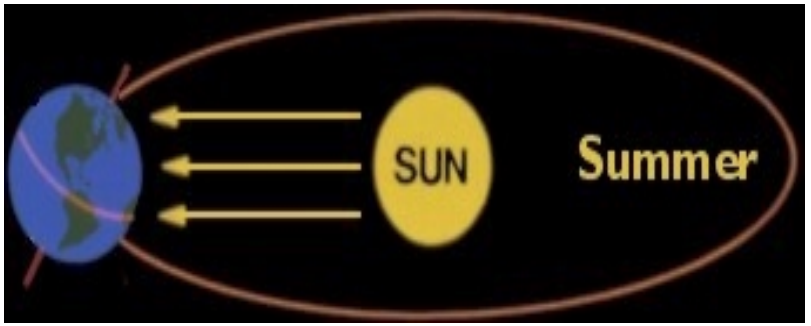
- The Earth is the third planet from the sun and the fifth largest planet in the solar system. It is the only planet in the solar system that is known to have evolved life. The Earth's orbit around the sun is almost circular at a distance of 93 million miles (149,000,000 kilometers) or one Astronomical Unit (AU). It takes the Earth 23.93 hours to rotate once around its axis and it takes the Earth 365.26 days to orbit (revolve) around the sun.

# EARTH’S SEASONS

- The seasons are the result of the tilt of the Earth's axis. The Earth's axis is tilted from perpendicular to the plane of the ecliptic by 23.45°. This tilting is what gives us the four seasons of the year, Summer, Autumn, Winter, and Spring. Since the axis is tilted, different parts of the globe are oriented towards the Sun at different times of the year.

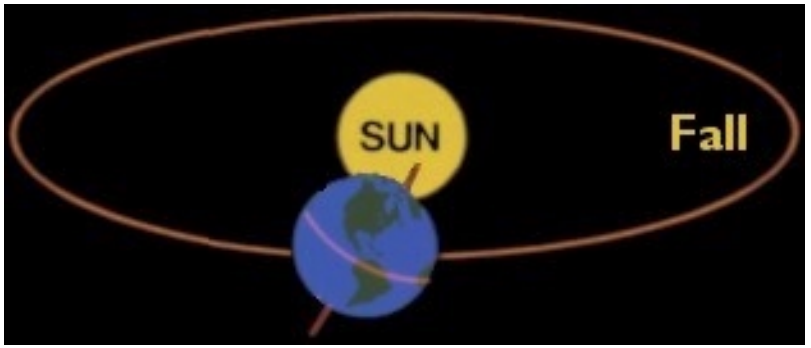
# Summer

- Summer solstice (June 21): northern hemisphere is tilted toward the sun during summer. Sunlight focuses on and warms the northern hemisphere. It is the longest day of the year.



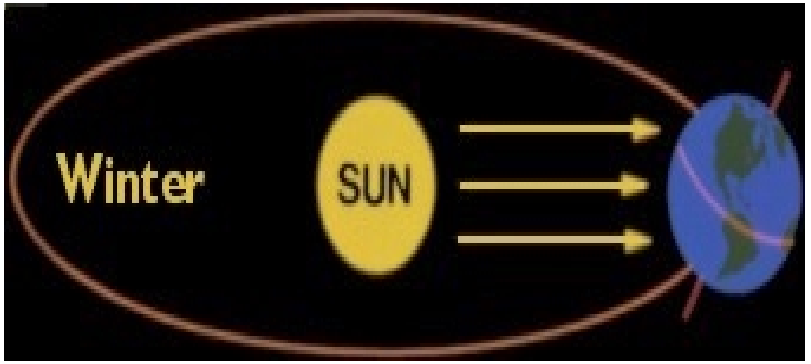
# Fall

- Fall equinox (September 21): neither hemisphere is tilted toward the sun. Both hemispheres do not have extreme heat of cold. Sunlight focuses on the equator. Day and night are of equal length.



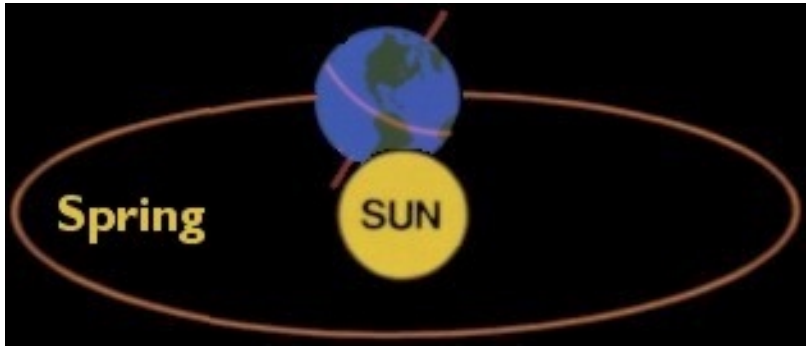
# Winter

- Winter solstice (December 21): northern hemisphere is tilted away from the sun during winter. Sunlight focuses on and warms the southern hemisphere. It is the shortest day of the year.



# Spring

- Spring equinox (March 21): neither hemisphere is tilted toward the sun. Both hemispheres do not have extreme heat of cold. Sunlight focuses on the equator. Days are of equal length.



# DAY AND NIGHT

- Day and night are the result of the Earth's rotation on its axis. It takes 23.93 hours to complete one rotation. As the Earth rotates, only one side of the Earth faces the Sun (day) while the other side is away from the Sun (night).

# THE MOON

- The moon is Earth’s only natural satellite. The moon is a cold, dry orb whose surface is studded with craters and strewn with rocks and dust . The moon has no atmosphere.  The same side of the moon always faces the Earth because the Moon rotates only once as it revolves around the Earth. The far side of the moon was first observed by humans in 1959 when the unmanned Soviet Luna 3 mission orbited the moon and photographed it. Neil Armstrong and Buzz Aldrin (on NASA's Apollo 11 mission, which also included Michael Collins) were the first people to walk on the moon, on July 20, 1969.

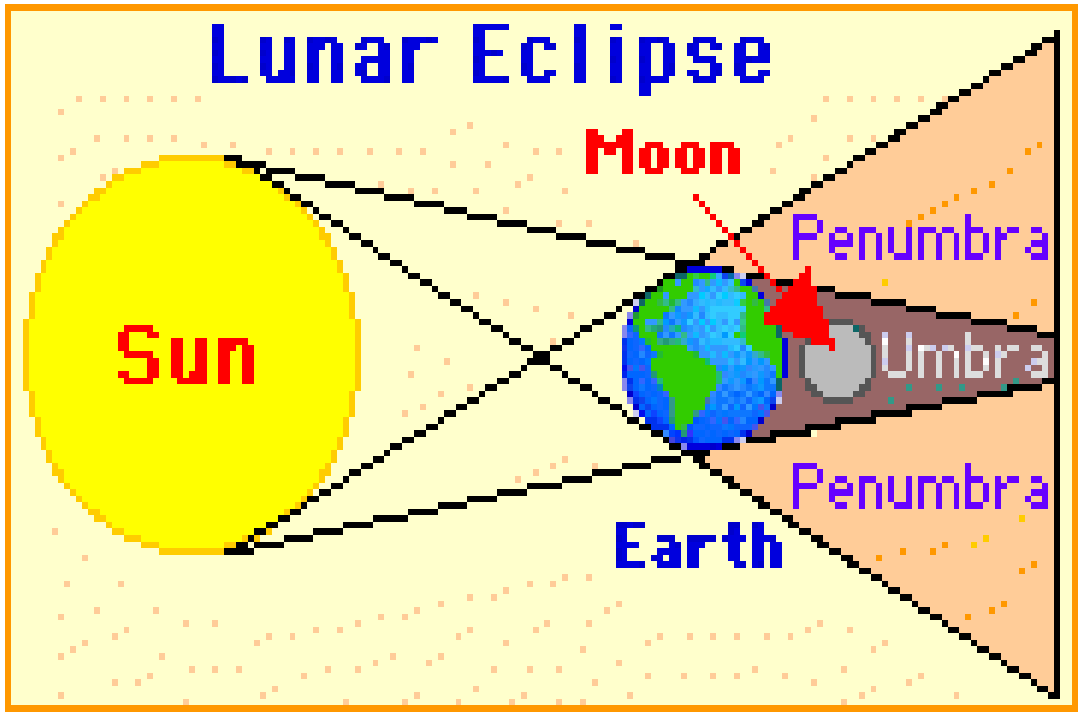
# LUNAR ECLIPSE

A Lunar Eclipse occurs when the Moon enters the Earth's shadow. During this event, less sunlight reaches the Moon and its appearance changes. During a total Lunar Eclipse, the Moon is entirely inside the Earth's shadow; during a Partial Lunar Eclipse, only part of the Moon is inside.
A Lunar Eclipse always happens at the time of the full moon, when the Sun, Earth, and Moon are (nearly) aligned. Lunar Eclipses are global events that can be observed from many geographical regions on the Earth. Lunar eclipses occur, on average, about every 6 months.

# TYPES OF LUNAR ECLIPSES

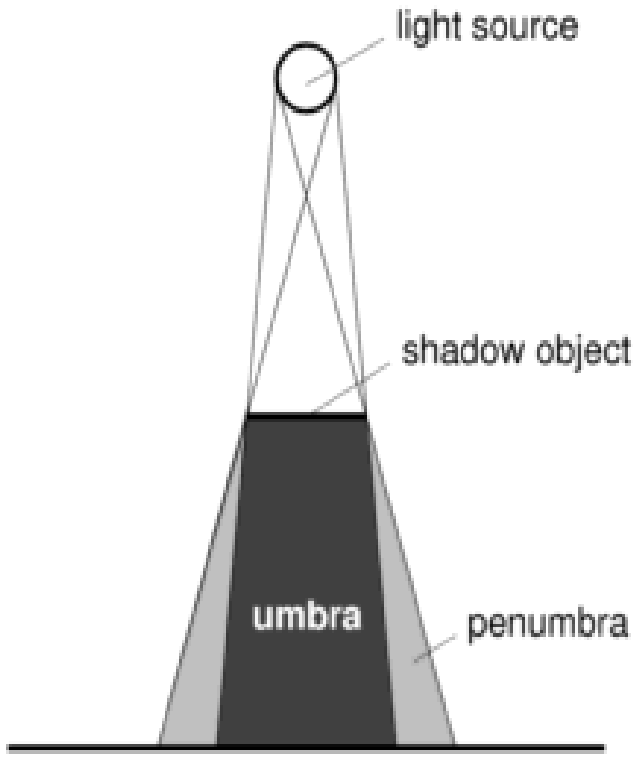
- Total Eclipse - When the entire moon enters the Earth's umbra (the darkest part of its shadow), this is called a total eclipse.
- Partial Eclipse - When only part of the moon enters the Earth's umbra, this is called a partial eclipse.

# DIAGRAM OF A LUNAR ECLIPSE



# UMBRA AND PENUMBRA

- The shadow volume behind an object lit by an area light source (in contrast to a point light source) doesn't have sharp boundaries. This is caused by the fact that each point in the boundary area is only partially shadowed. The area (volume) in full shadow is the **umbra**, the boundary area the **penumbra**. When the moon is entirely within the umbra, the eclipse is total. If the moon is within the penumbra, there is a partial lunar eclipse.



# PHOTOGRAPHS OF A LUNAR ECLIPSE

# PHASES OF THE MOON

- As the moon circles the Earth, the shape of the moon appears to change; this is because different amounts of the illuminated part of the moon are facing us. The shape varies from a full moon (when the Earth is between the sun and the moon) to a new moon (when the moon is between the sun and the Earth).